III. CHARACTERISTICS OF A SOLAR-TERRESTRIAL OBSERVATORY

A. Approach

Operation of an effective Solar-Terrestrial Observatory will depend on our capability to make comprehensive simultaneous measurements using *in situ*, remote-sensing, and active probing techniques. These measurements should be made continuously or with sufficient frequency over time scales adequate to record the diurnal, solar rotational, seasonal, and solar-cycle variations which are thought to hold the key to our understanding of many of the important solar-terrestrial interaction mechanisms.

The needed measurements and investigations, outlined in the previous sections, place certain general and specific requirements on the platform to be used, on its orbit, and on its complement of instruments. The following paragraphs outline a number of these requirements as presently envisioned.

B. Orbit

Low-altitude orbits are well suited for many of the required monitoring and experimental operations. Initial operations (for example, solar observations) could begin at any inclination. For studies of the energy input to the atmosphere resulting from magnetospheric activity and

solar-flare protons, a high-inclination orbit (> 65°) is preferable. Certain magnetospheric and atmospheric investigations can be conducted from a lower (< 58°) inclination orbit, but their scope is limited. Second-generation observations at geosynchronous orbit would be extremely useful for in situ measurements of magnetospheric energy transport processes combined with continuous remote-sensing observations of the Sun and an entire atmospheric hemisphere.

This pattern of orbital requirements is quite compatible with an evolutionary sequence envisioned for Space Station development. If a low-altitude station were maintained as a way station to a geosynchronous station, a Solar-Terrestrial Observatory could productively be a module in both.

C. Platform Characteristics

Provisions must be available for the pointing of individual instruments independently of Space Station attitude. The observing requirements will include cryogenically cooled instruments and large instrument arrays. These must be pointed at the Sun, at selected solar features, at selected atmospheric locations (including limb scanning), and simultaneously up and down magnetic field lines. Pointing requirements will vary from a fraction of an arc second for some of the solar

instruments, through $0.1°$ for selected atmospheric remote-sensing instruments and electric or magnetic field detectors, to $1°$ for the magnetospheric particle detectors.

The observatory should be equipped with a data processing facility capable of reducing data from onboard instruments and combining it with real-time data from supporting subsatellites and the ground. In-orbit laboratory facilities are required for the testing and possible modification of selected onboard instruments, including optical systems. An EVA capability would be extremely useful in the repair and maintenance of instruments.

D. Manned Operation

Operation of the Space Station observatory would be optimized in many respects by a manned facility. The use of a properly trained onboard scientist is expected to be quite cost effective in the performance of active probing experiments using man's superior pattern recognition capability and ability to respond to the unexpected. In the remote-sensing and direct-measurement operations, a man-in-the-loop concept is also expected to add significantly to the versatility of the observatory and to the optimization of its observing capabilities. He would be able to accomplish onboard calibration, repair, maintenance, and instrument

improvement as well as data processing and analysis.

The large coordinated observing programs involving observation of specific cause-and-effect links between Sun and Earth will be greatly enhanced by manned operation, with the onboard scientist examining the results and then configuring and carrying out the follow-on experiment. Although the Solar-Terrestrial Observatory experiments will be enhanced by man's presence, they will not necessarily require continuous manned operation because many of the observations can be carried out in a semi-automated fashion.

E. Duration of Observations

Long-duration operations are essential in order to study and monitor the diurnal, solar rotational, seasonal, and solar-cycle variations that are important aspects of solar-terrestrial interactions. Realization of an effective program of long duration requires the ability to calibrate, repair, maintain, and upgrade the onboard instrumentation to as great a degree as possible.

F. Subsatellite Clusters or Ensembles

A number of the anticipated instruments will be large and massive because of cryogenic cooling, substantial energy storage requirements, and

optical systems complexity. These instruments will require the accommodations of a Space Station module and exposed platform. On the other hand, other instruments, while much smaller, will require freedom from electromagnetic and chemical contamination, and perhaps direct access to rather remote regions of the magnetosphere or to the solar wind.

It is anticipated, then, that accomplishment of the objective of a Solar-Terrestrial Observatory will require a cluster or ensemble of small subsatellites able to transmit data directly back to the main observatory. An example of this operation would consist of a subsatellite in heliocentric orbit monitoring the solar-wind variations, with another satellite in the magnetosphere near the observatory monitoring ambient plasma conditions outside the disturbed electromagnetic environment of the large Space Station. Information from these subsatellites would be telemetered to the observatory.

G. Instrumentation

In order to make the comprehensive simultaneous set of measurements required for the solar, magnetospheric, and atmospheric observations, a large observatory is visualized. A modular approach in which instruments with similar pointing, power, thermal, and data handling requirements are grouped in various combinations may facilitate the

overall integration and operation of the observatory.

The instrumentation consists of three major categories: remote sensing, active probing, and passive *in situ* diagnostics. The study of solar processes will be done with remote sensing techniques which have evolved out of the Skylab missions. Remote sensing will also be used to sound the Earth's atmosphere for concentrations, temperatures, and winds. The active experimentation, consisting of particle accelerators, transmitters, laser radar systems, and gas release mechanisms, will seek to probe the magnetosphere and atmosphere around the observatory and measure the response of the system. The passive *in situ* diagnostic instruments will constantly monitor the state of the magnetosphere and will provide the background information needed to conduct the active experiments.

All of these instrument and experiment techniques can be developed on the short-duration sortie mode flights of the Spacelab/Shuttle. Their application to probing solar, magnetospheric, and atmospheric processes will be well proven for long-duration use in the Solar-Terrestrial Observatory.

IV. CONCLUSIONS

The evidence is overwhelming that the solar-terrestrial environment is a dynamic, tightly coupled, interactive system in which variable solar energy is transmitted through electromagnetic radiation and the solar wind to the Earth's magnetosphere and atmosphere. The constantly changing solar input coupled with the continuous redistribution of energy near the Earth constitute the external boundary conditions which determine the characteristics of our global environment.

An understanding and subsequent management of this environment will require a well-planned, coordinated set of observations of solar processes and the accompanying magnetospheric and atmospheric responses. A major element in this observational plan should be a Solar-Terrestrial Observatory module of a manned Space Station which would be operational initially in a low Earth orbit with a follow-on mode at geosynchronous orbit. The Solar-Terrestrial Observatory would be a self-contained module and exposed platform facility which includes a variety of remote sensing, active probing, and passive diagnostic instrumentation. It would also include a computer facility capable of interrogating and processing information from several subsatellites located in the magnetosphere and the solar wind. The manned activities would center around the conduct of coordinated experiments, repair and calibration of the instruments, and

onboard analysis of the experimental data. The highly trained scientist participation will insure a flexible and evolutionary operation of the observatory.

The mode of operation of the Solar-Terrestrial Observatory would change with time. Initially it would focus upon filling in the missing pieces in a working understanding of the solar-terrestrial environment. Ultimately it would reach an operational phase in support of useful predictions and forecasts for numerous environmental factors. The mature operational phase would utilize an observational mode that adapts to circumstances as they occur, in contrast to a purely monitoring mode. As in the case of present hurricane tracking, the Solar-Terrestrial Observatory would, for example, adapt its observations to follow the course of events of a major solar flare and its impact on the Earth. This capability distinguishes the observatory as an appropriate element of a permanent manned Space Station.

In the operational phase, the list of factors worth predicting grows with the climbing complexity of civilization. Already many examples can be cited. Agriculture, from the grass-roots farmer to the senior government official, requires reliable short-term weather predictions and long-term climate forecasts. Lawmakers require a knowledge of the effects of man-made pollutants on the atmosphere to provide a basis for protective

legislation. Communication activities need warnings of ionospheric disturbances. Electrical power distributors must be made aware that coming magnetic storms may induce currents that will throw circuit breakers throughout their networks. Prospectors for mineral resources can benefit from a preknowledge of periods of magnetic quiescence propitious for magnetic prospecting. Air and sea transportation can save substantial monies and precious fuel if they can schedule their trips in accord with meteorological expectations.

All of the previous examples are real in the sense that they are being done now in the restricted ways that are possible with our limited knowledge of the solar-terrestrial environment. Much more can and must be done in the complex civilization of our future.

The concept of Earth as a spaceship has gained recognition in recent years. Thanks to the space program, it is an image which is readily appreciated, connoting as it does an object with limited resources and an environment with limited capability. Unfortunately, the analogy is becoming increasingly apt as the world population grows inexorably and as developing nations, which are striving for some form of quality-of-life parity with their wealthier neighbors, increase per capita consumption of both energy and raw materials. This two-pronged forcing function is pushing us toward limits of natural resources and limits of the ability of

the environment to cleanse and renew itself. This nation cannot control world population nor the aspirations of developing nations. It can, however, determine the limits of the life support system and how it can be managed for optimal effect. In the past this was neither possible nor necessary; the scale of human impact was far below the scale of global resources. To date we have experienced only the initial ripples of the economic consequences of approaching global limits of natural resources and only isolated instances of the physical limits of our environment. For the future, ignorance will be a luxury we cannot afford, and knowledge a requisite for survival.

The Solar-Terrestrial Observatory, with its long-duration manned mission and simultaneous measurement of the relationship between solar activity changes and terrestrial response, will provide us with the insight and understanding necessary to model and predict changes in our complex but delicate environmental system. It will allow us to more fully understand our Sun-Earth system. It will place man in a better position from which to manage his environment, to plan the use of his resources, and, in short, to control his destiny on this planet.